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ABSTRACT

The electromagnetic environment has a great amount of influence on the existence of life and man. The main points of concern are--(1) that sea-level solar radiation is biologically beneficial and necessary for man's physical and mental health, (2) that urban man has inadequate exposure to certain wavelengths of ultraviolet light normally received from sunlight, and (3) that man has created an electromagnetically polluted environment that is potentially harmful to life. Data references and observations supporting the above statements indicate that man must be concerned with creating a biologically optimum electromagnetic environment. To achieve this, the author cites a need for the creation of a profession called spectrum engineering, which would be primarily concerned with electromagnetic radiation and its biological effects on life. An important aspect of this concept is "bio-lighting", an artificial light source that would produce a quality of light the approximate equivalent of sunlight found at sea-level. A listing of the effects of various wavelengths of solar radiation on life, and a list of references, are appended. (JD)

The University of Wisconsin

UNIVERSITY EXTENSION
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LIGHTING TECHNIQUES IN ARCHITECTURE

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"BIO-LIGHTING"

a presentation by

H.L. Logan
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Bronxville, New York

B I O - L I G H T I N G

H.L.LOGAN

INTRODUCTION

As Apollo 11 rounded the dead, white face of the moon last Christmas Eve, Captain James Lovell looked from it

S L I D E 0 THE EARTH AS SEEN FROM THE MOON

back to the bright blues and rich browns of our little planet riding through the emptiness and said: "It's awe-inspiring. It makes you realize just how much you have back there on earth. The Earth from here is a grand oasis in the blackness of space".

This magnificence is largely owing to the earth having just the right mass to have the gravitational pull which will hold just the right atmosphere to permit an electromagnetic environment favorable to life from the lowest to the highest forms.

OUR ELECTROMAGNETIC ENVIRONMENT

The natural electromagnetic environment produced by the solar radiation that gets through our atmosphere is necessary to life, and particularly necessary to optimum human, physical and mental health. All life on this planet runs on solar radiation, according to Nobel Prize Winner, George Wald.

According to McLeod (and many others) modern man in the United States, and other industrialized nations has created a menace. He worships at the shrine of personal cleanliness, creature comforts and new techniques while surrounding himself with a polluted environment.

One of the important concerns behind the National Safety and Health Act of 1968 was the electromagnetic jungle (with its resultant electromagnetic "smog"), man is creating through the electronic devices he is proliferating. He is proving susceptible to damage of various kinds, such as developing cataracts when exposed to microwaves of some frequencies, unstable mental states when exposed to even very low levels of UHF waves, and when exposed to the infrasonic modulations developed by machinery and moving parts, which are in the neighborhood of 10 cycles per second, which is right on the alpha rhythm of the brain, and when exposed to unbalanced frequency patterns from visible radiation, or "light", and so many other types of biological damage from various distorted combinations of frequencies, in and out of the "light" region of the spectrum, that time does not permit listing them .

Also, while investigators are finding out that man needs exposure to natural electromagnetic radiation, in order, among other things, to keep his senses tuned up, they discover he is going in the opposite direction and denying himself many natural benefits. With modern living in fireproof buildings which attenuate external, natural electromagnetic fields; with artificial lighting at a set, static intensity, using a bob-tailed spectrum of unbalanced frequencies which depart from the frequency patterns under which our nerve network characteristics have evolved; plus air-conditioning which excludes natural variations in ionization and upsets the normal oxygen balance in the air, medical authorities are beginning to wonder what the cumulative effects may be. Another SILENT SPRING may be in the making, quite different to what Rachel Carson was thinking about unless we begin to restore electromagnetic compatibility to our artificially created environments.

ILLUMINATING ENGINEERING

As illuminating engineers we have mainly concentrated on applications of the visually potent electromagnetic frequencies or "LIGHT", unaware that events are out-running us. Buckminster Fuller, possibly the most advanced architect in this

country today recently said, "The important thing to realize is that 99.9% of all the important research that is now going on, that is going to change our tomorrow, is going on in the areas of the electromagnetic spectrum". Illuminating engineering must expand into SPECTRUM ENGINEERING.

Why? Because the long-term physical and mental health of the urban inhabitants of the Western world is at stake.

THE URBAN PROBLEM

In 1900 A.D., eight-five percent of our people were rural. Now eight-five percent are urbanized. They are indoor people whose means of livelihood, location and conditions of living deprive them of access to enough life-sustaining electromagnetic radiation. Dr. J. P. Pickard, of the Urban Land Institute, says that by 2000 A.D., three huge megalopolies will house 60% of the projected 300 million people in this country, or 240 million.

This rush to the cities is one of themain reasons peoples of the Western world, with their long winter sun lack, plus all-year living, learning and working indoors, (in cities with polluted atmospheres which cut the biologically beneficial rays 30%, and behind window glass which cuts out all the rest), find their death rate peaking in March.

Some scientists believe that a potential life of from 125 to 175 years is inherent in man. Some people have lived to beyond 150 years, as witness the famous case of Thomas Parr who was born in 1483 in Winnington, Shropshire, England and died in London in 1636.

There is a story that he first came to public attention when he was arrested for rape at the age of eighty. Sir William Harvey, the discoverer of the circulation of the blood, performed the autopsy on him. He reported all his organs were in perfect shape; that his death was really premature, owing to the decision of the Earl of Arundel to exhibit him at the Royal Court, where the change of air to foggy, smoky London with its reduced sunlight, and the over-rich diet, killed him in 1636. He is buried in the south transept of Westminster Abbey.

The probabilities are that we are now attaining only half our potential life span; and unless we introduce the beneficial effects of sunlight into our interiors we may not raise life expectancy much beyond the present 70 years. Indeed, in 1968 our national life expectancy dropped for the first time in the last twenty years.

Professor L. K. Caldwell of Indiana University and F. Sargent of Wisconsin University said at Warrenton, West Virginia last November 26th, that "a program to halt the deterioration of Man's environment was as urgent as the Manhattan Project to develop the atom bomb nearly three decades ago".

The work of the world, for protection from the hostile swings of nature, has gone "indoors". The rush to an artificial environment has speeded up so much that in 1975 it is expected that 93% of our people will be crowded into urban areas. They will have left the sun outdoors without which life, in the long run, is impossible. Present artificial light lacks the essential bio-effects, and so does natural light through windows. Artificial climates protect against nature's extremes but can hardly be said to invigorate.

Where the workers live in most of North America and Western Europe there is no practical possibility of their getting a minimum necessary <u>daily</u> ration of solar radiation except in summer. The sun does not rise high enough in the winter for its life-giving rays to be adequate, even if people were not living in polluted atmospheres; which is perhaps why the Russians have been the first to make practical, large-scale application of what I have come to call "BIO-LIGHTING"; and why they are developing a literature of the pathology of "light-hunger".

Until now, as I implied earlier, we have been concerned with what I call "VISI-LIGHTING" - lighting for visibility. We have ignored the non-visible and extra-visual properties of the sea-level solar electromagnetic spectrum, of which light is only a small part. It is only in this century that these parts of the solar spectrum, now shown on the screen, have been investigated for their biologically

S L I D E 1 (E.M. SPECTRUM)

beneficial, or harmful, direct or side-effects.

Light is that part of the sea-level solar radiation lying between 380 and 770 nanometers. The entire sea-level solar radiation spectrum covers from 290 to 2800 nanometers. "Light" is just a small part of it, but all of this radiation is received by the eye, and the eye is affected by it. The "light" part of this radiation is used by the eye, to provide optical images of the outside world, i.e., to operate the sense of sight. The non-light part of this radiation is used by the eye, synergistically with the "light" part, in co-operation with the skin to develop homeostasis - a condition of equilibrium between the needs of the body and the demands of the external environment. This non-visual function is so important that Dr. R.J. Wurtman of M.I.T., concludes that "light (including its accompanying side-bands of electromagnetic radiation), is the most important environmental input, after food, in controlling bodily function.

The degree to which solar radiation affects the operation of the body and its state of well-being or deficiency is incredible to the uninitiated, but perhaps the most important thing it does is to generate Vitamin D. Vitamin D is of vast importance to mankind and it appears to be one of the factors that has determined the development and distribution of the races.

This has a special bearing on sick people, involuntarily captive in hospitals and Children, herded indoor in schools, during that part of the year when solar radiation is at its lowest ebb in the Temperate zones where people mostly are, and such as it is, available for the fewest hours per day.

The general thrust of the evidence is that an adquate daily dose of sea-level solar radiation affects their generation of Vitamin D, their physical development, their blood count, the indices of inorganic phosphorus content, the activity of alkaline phosphotase in the blood, the gammaglobulin content, their over-all immunological responsiveness, their achievement potential, and their mental stability.

Just one detail - researchers report that exposure to the proper dosage and frequencies of ultra-violet radiation results in a drop in blood pressure. In patients with arterial hypertension the fall is most pronounced. This is interesting when taken in conjunction with the U.S.Army report that significant signs of hardening of the arteries is higher among troops in the 18 to 23 year age group than in previous wars. Returning to mental stability Entwhistle has stated:-

"We see today in the organism sector of the human ecosystem a continual increase in the symptoms of cultural degeneration in our urban centers. Apart from the juvenile delinquency and the penetration of the roots of crime into every level of our society, functional disorders of the nervous system are increasing by leaps and bounds".

Light has a powerful influence on the nervous system. First, there is the effect of light directly, in entering the body through the eyes and the skin, then being transformed into nerve pulsation frequency patterns, going to various destinations internally, which respond, such as controlling the various biological "clocks" or circadian rhythms, speeding or slowing the release of hormones into the blood stream, and innumerable other biological effects.

When light so transformed reaches the higher centers of the brain it causes all the emotional tones from ecstasy to agony, such as when suddenly exposed to a beautiful nude, or seeing one"s home on fire. When there is excessive entropy or disorder in the patterns, such as those caused by frequency patterns having rates lying in the frequency range of the brain waves, violent nausea may be induced, or even complete unconscious, in a matter of seconds. (This is, in fact, being experimented with for military applications). It would be interesting to see the effect of combining these frequency patterns with infrasonic frequencies of 10 cycles per second, mentioned earlier.

Going to the other end of the scale, experiments by Heron, Doane and Scott have shown that "exposing subjects to a monotonous sensory environment can cause disorganization of brain function similar to, and in some respects as great as that produced by drugs such as LSD, or brain lesions"

During the Korean conflict the effect of sensory deprivation was observed in American prisoners of war who were placed in a highly controlled environment, impoverished of compatible sensory stimuli. Sensory deprivation may be an element of importance in the etiology of mental disturbance, according to Drs. Leiderman, Mendelson, Wexler and Solomon. They report "Mental abnormalities can be produced in many normal persons when they experience sensory deprivation". In one case moving the subjected to a well-daylighted room resulted in a complete return to mental clarity. They state "We are presenting these cases in order to illustrate the applicability of the concept of sensory deprivation (or adulteration) in clinical medicine. We are not attempting to establish its validity on a statistical basis. This can only be done through the work of many investigators, who will complete and examine their own clinical material with this concept in mind".

Dr. L. Schneider of Munich says "Activity of the brain, particularly when handicapped by inadequate or distorted sensory information, such as that caused by frequency patterns which are difficult for the nervous system to cope with, results in central or general fatigue. This affects the autonomic (involuntary or reflex) nervous system, and by changing the control mechanism of this system it can, in extreme cases, paralyze voluntary action".

Hollwich proved that, apart from the influence of the luminous stimulus via the optic nerve on the orientation reflex, the water balance in the body was affected,

so was carbohydrate metabolism, the level of adrenalin in the blood, and the functioning of the thyroid. As the diencephalon-pituitary gland system is part of the central nervous system, where physical phenomena are transformed into emotions, it is obvious that the frame of mind and mental health of an individual, as well as his or her achievement potential, can also be influenced by the make-up of the electromagnetic field in which he or she is immersed. It is a small step to the conclusion that the character of the environmental electromagnetic field has a direct bearing on mental, as well as physical health.

A fill-in detail on this is the study by Dr. S. F. Korbel of the University of Arkansas, that some radiation frequencies emitted by artificial sources influence mental and emotional activity, particularly by increasing irritability and nervous tension, apparently as a result of causing the accumulation of acetylcholine in the system.

In any event, the Joint Committee on Mental Health of Children reported on October 25th to Congress that ten million under age 25 need mental care. It seems to me that there is more than a suspicion that the type of electromagnetic environment we have created has some relation to this sad fact.

We do know that it has major effects on women. When the solar electromagnetic field is practically absent for long periods such as in polar regions inhabited by Eskimos, the women neither menstr/u/ate nor conceive during the long polar night. Children have to be suckled for from four to six years, and on the average one child is born every four years.

I could go on almost endlessly detailing the effects of what you call "light" on people, of which people are totally unaware. I will return to Dr. Schneider's work for just one more point. He says, "central fatigue of the brain is one of the effects of a combination of insufficient light, plus incompatible frequencey distribution

patterns, and that work disposition improves with general lighting of high level and a TRUE WHITE COLOR."

COLOR

The true white color which is the memory reference standard of the Western industrialized nations has been established by the International Congress on Illumination, as average daylight throughout the North Temperate Zone. The International Commission on Illumination has determined this to be sea-level solar radiation frequency distribution at 5500° K.

THIS IS THE ELECTROMAGNETIC SPECTRUM WE SHOULD DUPLICATE FOR INDOOR LIGHTING.

S L I D E 2 5500° K CURVE

Illuminating engineering research on visibility for VISI-LIGHTING has been largely concerned with identifying and measuring hindrances to contrast difference perception - that is brightness differences in a non-existent black-grey-white dream world. Color contrast has been ignored.

Optical efficiency can be theoretically measured by determining the number of bits/sec of information transmissible under optimum conditions. This has been done by Dr. Weber of Brooklyn College on the basis of minimum discernible visual detail, maximum rate of fusion of the mosaic pieces, in a black and white world: that is on the basis of brightness differences. He says the "increase in informational capacity from color perception has been ignored". He does not think that it would triple the capacity, but if it only added 50% that would mean that lighting levels in a world where the frequencies in the light where similar to 5500° K, would give equal information at levels one-third below that needed for brightness contrast alone.

We don't know how much enrichment of information color contrast adds to the field of view, but THE ADDITIONAL DATA it provides is on the nature of the surface

it reveals, and sharpened form discrimination. If the illuminant color is true white there is improvement in perception; improvement in reflexes because the nervous system is designed to operate most efficiently with the natural frequency patterns, and improvement in the anticipatory timing of behavior. That it adds considerably is evident from the following simple illustrations.

S L I D E 3 NO COLORS DEER

S L I D E 4 COLORS DEER

S L I D E 5 COLOR CHART - BRIGHTNESS DIFFERENCES ONLY

S L I D E 6 COLOR CHART - IN COLORS

This is important because by adopting the proper frequency distribution, i.e., the natural distribution, we get this bonus in seeing ability and enjoyment on top of the biological, physiological and psychological benefits, which I have so inadequately outlined.

BIO-LIGHTING

To the objection that there are still gaps in our knowledge Dr. Wurtman observes "In spite of gaps we are still required to make decisions about the kinds of light under which people will spend most of their lives. We should worry now about the possible consequences biologically of our lamps before someone describes a new disease caused by bad light". Actually this disease may be already here in the flood of mental aberrations that are afflicting so many. If the defective artificial electromagnetic environment in which we are immersed is not the cause, it is surely a contributory factor.

He continues: "Are their any guide lines we can follow in designing light sources until we know fully how to evaluate their biological effects? I think so. First, we should begin to think of light as we would any other environmental factor

(food, chemicals, etc.,) that is known to influence biologic function. Until we know that it is safe to do so we should not allow the light provided by artificial sources to differ much from the light provided in our natural environment. The standard should be natural light as found in the temperate zones of the world".

The new field of BIO-LIGHTING gets its importance from a number of inter-related facts. First, although the body operates with a large safety factor in its life processes, it can operate efficiently only within a very narrow range of the external environment, and what physiologists call the "internal environment", by which they mean the body fluids, the composition of which is directly affected by "light".

Second, under optimum natural conditions, optimum homeostasis, (the desirable balance between the external demands of the environment on the body, and its internal adjustment to them), occurs automatically. Indoor, artificial conditions are not favorable to optimum homeostatis, as we have seen.

Third, the work of the world has come within arm's length, requiring close, detailed seeing, under conditions which protect the workers and learners from the hostile swings of nature, thus forcing them indoors.

Fourth, as a result, people must live in an artificial, closed circuit ecological system, which should be designed so that all their vital needs are satisfied.

Our next slide shows what we are heading into.

S L I D E 7 CALIFORNIA MEGASTRUCTURE

This is a megastructure to provide housing, service facilities, stores, offices, hospital
school/and recreation centers within one building complex. Everything will be within walking, or easy interior driving distance, and all needs will be supplied. It will be unnecessary to go outdoors and the time will probably come when to so so will be considered barbaric.

S L I D E 8 DISNEYLAND, FLORIDA

This slide shows that the three bottom floors of Disneyland in Florida, will all carry mechanical traffic of various kinds, and will be completely closed over. This means, if it is to operate successfully, complete control of the electromagnetic environment, and the atmospheric.

S L I D E 9 PROPOSED WATERFRONT COMPLEX, N.Y.C.

This is one of the new waterfront complexes proposed for New York City.

S L I D E 10 TOTAL HABITAT

This slide is called "Total Habitat" by the photographer, and shows one example of how far we have already gone, in developing what are now called "Ecosystems" for people. The vital function of the total habitat in the life and health of the organism is well-established in the biological sciences, and man shares this dependence. Our present artificial ecological system is no system at all. It has grown like topsy, without any co-ordinated planning and the results show in what is happening to people everywhere.

While office landscaping is generally thought to be an attempt to provide a psychologically pleasing environment, it is an unconscious response to meet the need produced by the oxygen imbalance caused by modern air-conditioning. The planting restores some of the depleted oxygen. However, the plants do not live successfully under artificial light, and a new profession has come into being - that of office-lanscape gardener, whose job is to try to keep them alive, and replace them as they wilt. If artificial sea-level radiating lamps were used, not only would the plants live, but more effective oxygenators could be used, and a much wider variety of plant life become available for this necessary indoor function. While modern buildings are more machine than forest, a good deal of forest beauty could be brought indoors with Bio-Lighting.

One thing seems clear; we cannot successfully live in the indoors, into which the human race is rapidly crowding, UNLESS WE TAKE THE SUN IN WITH US. The only practical way we can do this is to ARTIFICIALLY DUPLICATE SEA-LEVEL SOLAR RADIATION.

There are difficulties but none that can't be overcome. The expanded spectrum

S L I D E 10A (REPEAT SLIDE 2)

lamp that reproduces natural sea-level solar radiation is already available, but the criterion used by lighting engineers for evaluating artificial illuminants discriminates against the general use of sources duplicating natural sea-level radiation.

Obviously, a 40 watt solar radiator designed to produce the full, natural spectrum of raidant power, will not have as much of that power per watt in the

visible part of the spectrum, as a radiator designed to put the maximum concentration of radiation in the visible region, which is the case with present standard lamps. So a footcandle meter will show the solar radiator to be delivering say, 63 footcandles for the same wattage that a standard fluorescent lamp will deliver 100 footcandles. This kind of comparison will not reveal the physiological and psychological benefits of the invisible radiation from the solar radiating lamp, so new terms and methods of measurement must be developed to put all "lamps" on a common basis, solar and non-solar.

No matter how one looks at it there is nothing more healthy for people than proper daily exposure to sea-level solar radiation, either generated by the sun, or generated indoors by man: and the development of general lighting purpose, artificial sources along these lines is a "must" to protect people in our modern indoor world.

There is still some research spadework to be done. For instance, the effects of narrow spectral bands, and of various combinations of bands, are different, and they must all be searched out. As an example, exposure to radiation from the middle U.V. region alone is potentially dangerous.

S L I D E 11 MIDDLE U.V.

The next slide illustrates the fact that radiation from the near U.V. region is beneficial but it lacks the important ability to generate Vitamin D.

S L I D E 12 NEAR U.V.

S L I D E 13 NEAR AND MIDDLE U.V. COMBINED

This last slide shows that when the near and middle U.V. regions are combined in the proper proportions a tanning action occurs which protects against excessive dosage of middle U.V.

The rate of synthseis of Vitamin D must be regulated within definite limits if both failure of calcification and pathological calcifications are to be avoided. When middle and near U.V. radiations are combined in the proportions of sea-level solar radiation at 5500° K., Vitamin D biosynthesis is automatically regulated to the proper rate.

Most present lighting equipment is ultraviolet absorbing so that the benefits of solar radiating lamps would be cancelled out in totally enclosed equipment, and materially reduced in open equipment.

Glare is a severe handicap in critical seeing operations, so, at the high levels of light required for health, lamp-enclosed, or lamp-shielded equipment is necessary. At the same time most interior building finishes absorb ultraviolet, so the beneficial radiation has to be directed straight to the person. One cannot rely on reflection back from the environment. This dictates research aimed at developing new lighting equipment to meet these specifications, and possibly new light-handling materials.

Direct lighting methods will rule, which should be no surprise as direct lighting is nature's method. In order to conserve the therapeutic rays they will have to be controlled by suitable reflecting and transmitting equipment so that they are directed to people. The same methods that are used to control direct glare with direct lighting equipment will work to control the therapeutic component so that it is directed towards the workers instead of being wasted on the environment.

S L I D E 14 PHOTOMETRIC DISTRIBUTION

The type of photometric distribution shown on the screen would be ideal: practically no light in the direct glare zone and with less light vertically downward than from any other direction so that reflected glare would be minimal. The

The maximum candlepower would be 35° from the vertical, which is the optimum angle for vertical illumination and would be the most efficient for the delivery of the bio-rays.

The appearance of this distribution on a horizontal plane from one unit component of the lighting equipment is given on the next slide. In a complete lighting system the individual rings would disappear because of the overlap.

S L I D E 15 BASIC RAY STRUCTURE

Time has not permitted anything like an adequate introduction to our artificial electromagnetic environment. Most of the effects on people have had to be left out, and all of the effects on things and other forms of life such as the explosion of a missile at Cape Canaveral by extraneous, stray, artificially generated electromagnetic radiation, with a financial loss in the millions; the detonation of photographic flash bulbs in shelf storage; the malfunctioning of the RB-47 jet bomber owing to unexpected side-effects of radiation from one piece of equipment interfering with another; the upsetting of migratory bird patterns; the reduction of the return of homing pigeons in some areas from 95 to 98%; the erasing of intelligence from magnetic tapes; the interference of computers in one building with the operation of those in another building, and on and on.

Someone has to fit electromagnetic progress into incompatible environments. It has been pointed out that Labor can be affected by loss of jobs due to FCC violations where a company considers it cheaper to move to a new location than to try to shield or reduce radiation to acceptable levels in its present building or neighborhood. So Management's problems with labor will increase as new side-effects are discovered.

Events have made clear that the segregation of knowledge of sensory and biological responses, and the isolation from each other of their application techniques is destructive of co-ordinated design for working and living. This segregation cannot be maintained in face of the urge for better quality living. The need for bringing into being artificial environments completely compatible with man demands an integration of disciplines and techniques .

Packaging man so that his indoor artificial environment is compatible with him is the architect's responsibility, but he needs help. He needs a new breed of electromagnetic compatibility engineers, trained to protect and maintain both the outside and inside artificial environments, in which we can all live without paying physiological and other penalties.

In any event, where the health of people is concerned the reproduction of the natural sea-level electromagnetic environment is a big part of the answer. H.G.Wells once said "Civilization is a race between education and catastrophe", and Professor R.A.Falk of Princeton says "We live in a high-risk environment" (the understatement of the Century). Anything which reduces the risk is helpful. Environmental deterioration is one of the risk factors. BIO-LIGHTING will reduce this particular risk if we can educate people to the point where they will want it, SOON ENOUGH!

After all, the purpose of life is not to make a living, but to make life worth living!

SOME BIOLOGICAL AND OTHER EFFECTS OF SEA-LEVEL SOLAR RADIATION (AND OF "FAR U.V" OUTSIDE THE SEA-LEVEL SOLAR SPECTRUM) ON PEOPLE AND THINGS.

NANOMETERS	PROPERTY	REF.
290-2800	Range of radiation effective in causing photosynthetic and photoperiodic phenomena in plants[1], including growth and dormany centering on peaks at 440 and 660 nm	1 1a
	plus flowering and fructifying effects varying with species, such as the 290-380 nm band for ripening apples	2
	Photodynamic action	3
290-2000	Generation of atmospheric smog by conversion of innocuous air pollutants, via photochemical reactions generated by solar radiation, into irritating and corrosive compounds.	4
	Sexual maturity effect on blind people.	5
290-380 combined with 700 -2000	Ultraviolet and infra rays show antagonistic effects if used separately, but are synergistic if employed simultaneously. This is one example of photochemical antagonism of different regions of the spectrum.	6
290-1400	Skin reddening: capillary dilation.	7
290-1000	Region of marked photochemical activity (light-excited molecular activity).	8
290-800	Increase in volume of whole blood, and of hemoglobin. Increases insensible skin perspiration and decreases kidney load when frequencies are balanced as in solar radiation.	9,10
	Radiation through this range affects performance of neuroendocrine system.	11,12 13,14
	Influences enzyme production, circadianrhythms, including fertility cycle of women; chemical changes in genes, nerve impulse modulation	14a 15,16,17 18,19
	Reduces cancer metastasis	20,21,22 23,24

NANOMETERS	PROPERTY	REF.
290-700	Mutagenic action is common property of all radiant energy frequencies, except infrared.	25
	Irradiation increases mutation rate; the induced rate is independent of intensity; no threshold dose exists for the mutagenic effect of radiant energy, which shows complete accumulation over a lifetime.	26
	The yield of induced mutations is low. In the range of sea-level solar radiation it is almost completely countered by the synergistic photo-recovery action induced by the accompanying infrared radiation. This underscores the importance of providing people with the complete sea-level solar radiation spectrum in proper balance.	
350-700	This region affects photochemical reproduction processes.	27
380-775	This region affects the performance of the human photo-neuro-endocrine circuit, mediated through nerve fibre system "C", diencephalon, hypothalamus response: with indirect effects on the operation of the pituitary,pineal, thyroid, adrenal,pancreatic and sex glands.	28,29 30,31, 32,33, 34,35, 36,37
625-775	Photoblastic Red and Far Red effects: Gonadal stimulation	38,39 40,41
350-700	Optical effects: light and color sense: image sense: mediated through nerve fibre system "A":	42,43
	nausea and/or unconsciousness induced by flickering patterns having rates lying in the frequency range of the brain waves:	
	Objective orientation reflex; mediated through nerve fibre system "B"	44,45

NANOMETERS	PROPERTY	REF.
660-725	Photo-reversible reaction	46
290-600	Fading of colored textiles and other materials, including foods: (mild fading from 400 to 600 nm., rapid fading from 300 to 400 nm., very rapid fading and material deterioration below 300 nm.	47
330-480	Photo-reactivation of micro-organisms	48,49
220-400	Photochemical action on proteins, nucleic acids, viruses, bacteria and individual cells	50
300-420	Skin pigment darkening	51
290-380	Vitamin D synthesis	52,53, 54,55
	Effect on human light hunger pathology	56
	Erythemal and tanning effects	57,58,59
	Normalizes lime, phosphorus and calcium metabolism	60,61,62 63,64,65 66,67
	Increases protein metabolism	68
	Promotes blood clotting	69
	Reduces blood pressure in hypertensives; gives relief from angina pain	70
	Reduces blood sugar in diabetics	71
	Reduces frequency of respiration	72
	Improves work output	73
	Improves physical fitness	74
	Increases gamma-globulin fraction of blood	75
290-400	Controls high blood serum bilirubin levels in premature infants	83

NANOMETERS	PROPERTY	REF.
290-320	This "middle ultraviolet" band is responsible for the generation of anti-rachitic vitamins through photochemical synthesis in the skin. It can also cause skin damage when used independently. When used simultaneously with "near ultraviolet" (320-380 nm), in the proportions in which the two bands occur in sea-level solar radiation, plus continuous band radiation out to 2000nm, skin damage is prevented by a photorecovery mechanism (except where the radiation dose is greater than the photorecovery mechanism can handle).*	76
	*That is, more than 1 microwatt per second per square centimeter for greater than 8 hours exposure, initially, for white, untanned skin having a transparency of 97%. Skins of less transparency can accept a greater initial dose, up to 33 x for black skins.	76a 76b
250-320	Contributory to skin cancer under specific conditions. Most of this range is outside the range of sea-level solar radiation, i.e., exposure to 250-290nm radiation does not occur, as a practical matter, under natural conditions. Effective in the destruction of bacteria, mold, yeast and virus.	77
Below 340	Possible inflammation of conjunctiva, inflammation of cornea, and iris: photophobia; blaspharospasm; ciliary neuralgia.	
235-305	Effective in the destruction of bacteria, mold, yeast and virus	78,79,80
235-270	Potentially dangerous if used on humans. For 8 hour daily exposure the power density, at face level must be kep below 0.5 microwatts per square centimeter per second.	81

ANOMETERS	PROPERTY	REF.
elow 290	Can delay cell division: can delay synthesis of certain substances by cells; can change the ways in which substances cross cell membranes; can cause abnormalities in chromosomes; can produce mutations.	82
30-700	Range of frequencies which is responsible for vision. If the light from the field of view is both uniform and intense, such as can occur from a plain of snow in the daytime, snow blindness may occur caused by the piling up of energy at the crossing in the lens of the eye, resulting in the "cooking" of the albumen in the fluid in the lens. A similar result can occur from exposure to microwaves in the region of 3×10^9 H_Z, resulting in cataract formation.	

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